Decadal Missions Applications Workshop

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EOS & Other Missions Lessons Learned

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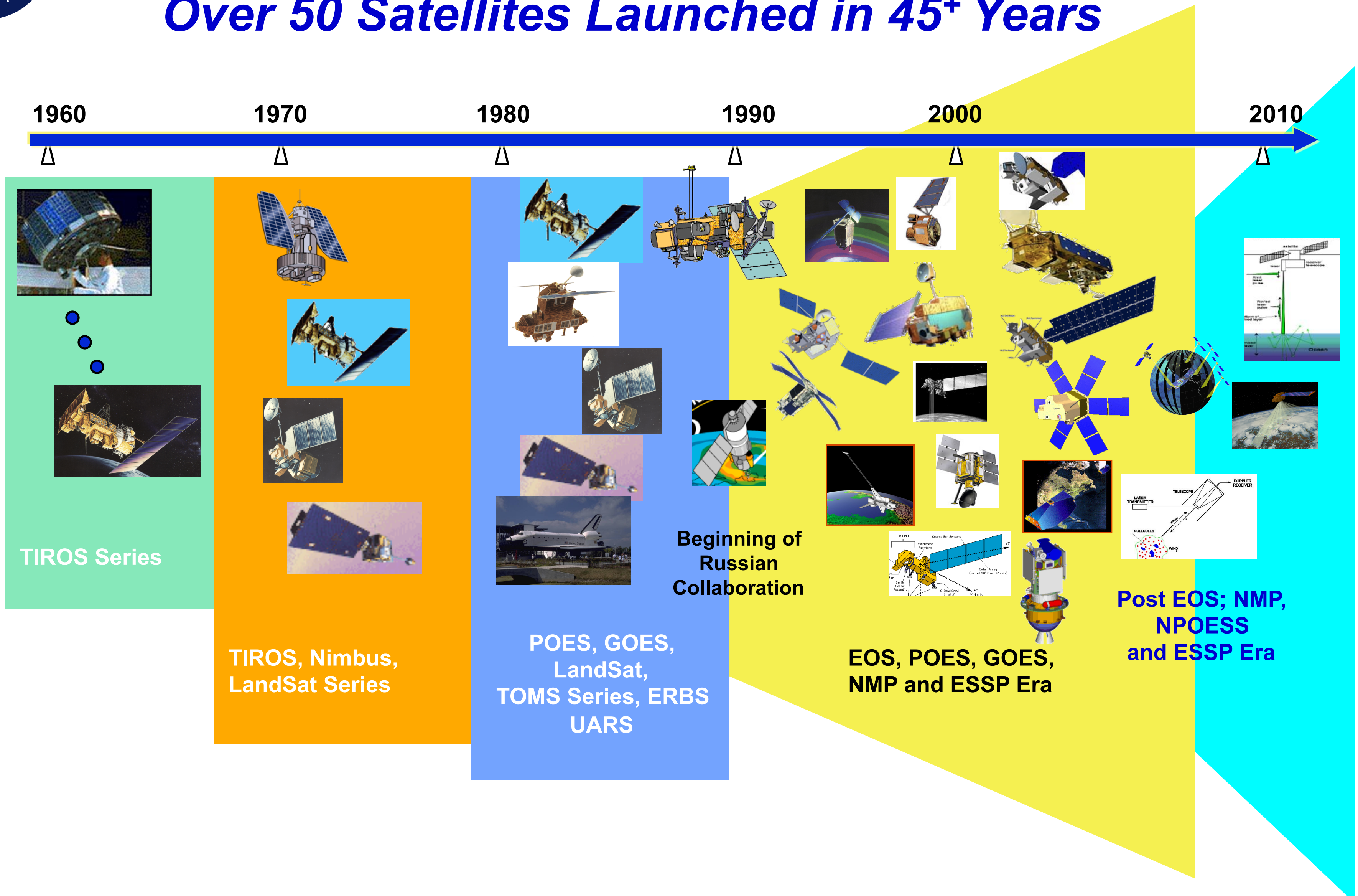
NASA's Earth Science Missions History

Missions	1960	1970	1980	1990	2000	2010
TIROS	x	x	x			
NIMBUS/ SBUV		x	x			
POES		x	x	x	x	x
GOES			x	x	x	x
TOMS		x	x	x	x	
ERBS			x	x	x	
UARS				x	x	x
EOS			x	x	x	x
NMP			x	x	x	
ESSP				x	x	

Experience and Heritage

Over 50 Satellites Launched in 45^{+} Years



EOS & Other Missions Implementation Model

- Earth Observing Systems (EOS) – Systematic measurements to build a long term time series to understand the climate variability

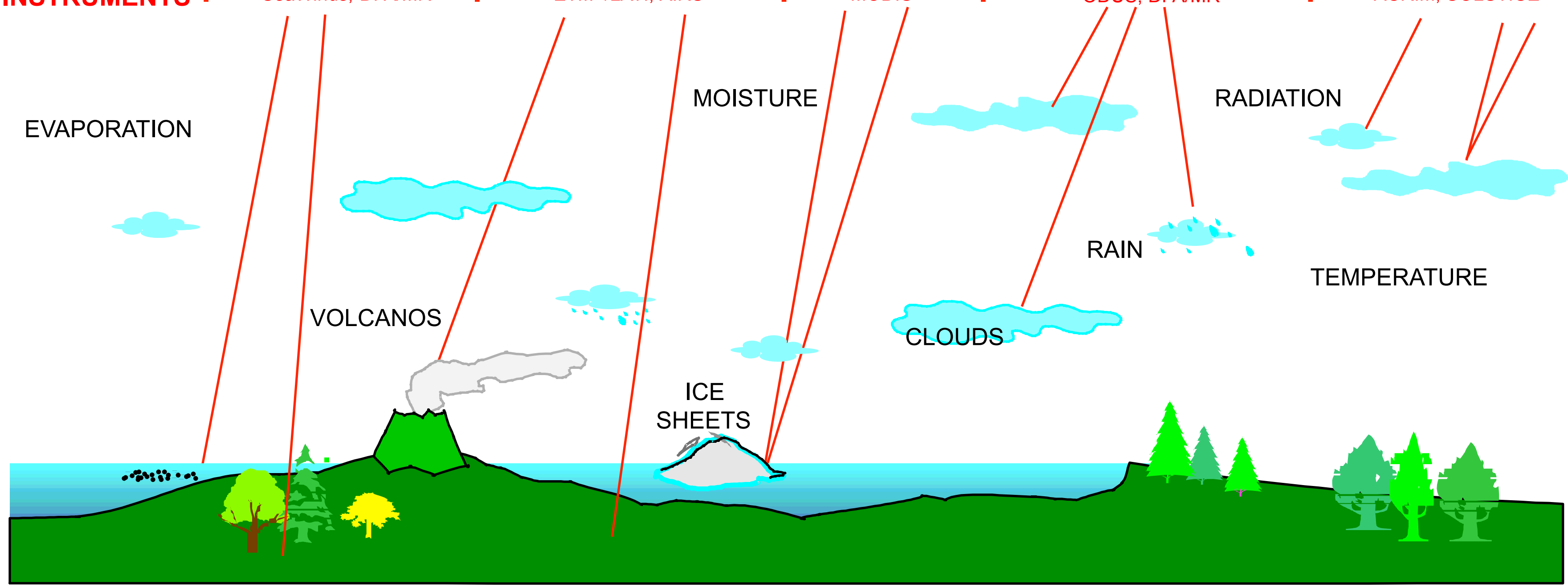
  - Identify 24 measurements to be made over 15-year period.
  - One-time solicitation of instruments to provide required measurements e.g., MODIS 1, MODIS 2, MODIS 3
  - Bulk of measurements to be provided by repeat flights of primary missions (AM series, PM series, Chem series).

- Earth System Science Pathfinder (ESSP) – Low cost, short life, quick launch missions to understand Earth processes not covered by EOS

- The “New Millennium Earth Observer” series of missions to flight-verify revolutionary technologies and promote industry partnership to address Earth science needs.

Mapping EOS Instruments & Measurements

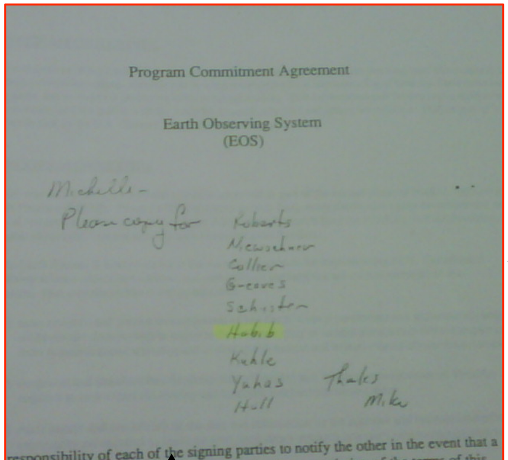
SCIENCE MEASURE-MENTS	Surface Temperature, Phytoplankton and Dissolved Organic Matter, Surface Wind Fields, Ocean Surface Topography	Land Cover and Land Use Change, Vegetation Dynamics, Surface Temperature, Fire Occurrence, Volcanic Effects, Surface Wetness	Land and Sea Ice, Snow Cover	Cloud and Aerosol Properties, Radiative Energy Fluxes, Precipitation, Tropospheric and Stratospheric Chemistry, Atmospheric Temperature and Humidity, Lightning	Total Solar Irradiance Ultraviolet Spectral Irradiance
SCIENCE INSTRUMENTS	MODIS, AMSR, AIRS, SeaWinds, DFA/MR	MODIS, AMSR, MISR, ASTER, ETM+/LATI, AIRS	GLAS, ASTER, ETM+/LATI, AMSR, DFA/MR, MODIS	MODIS, GLAS, AMSR, MISR, AIRS/AMSU, HSB, ASTER, EOSP, SAGE III, CERES, ACRIM, TES, MOPITT, MLS, HIRDLS, LIS, ODUS, DFA/MR	ACRIM, SOLSTICE

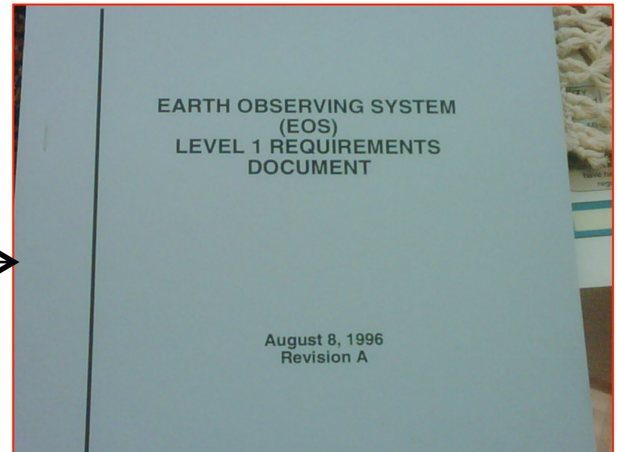


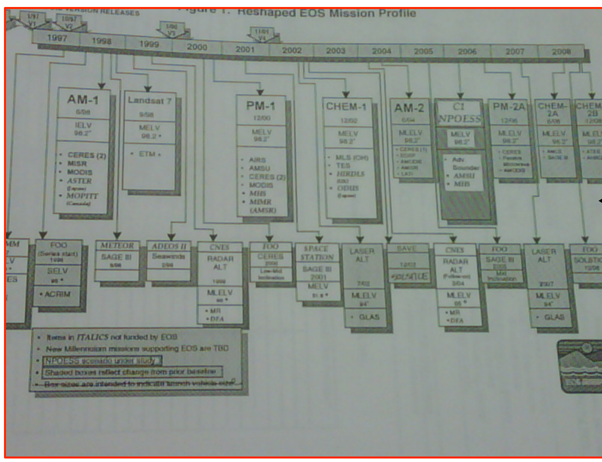
Seasonal to Interannual Climate Prediction **Decadal to Centennial Climate Variability**

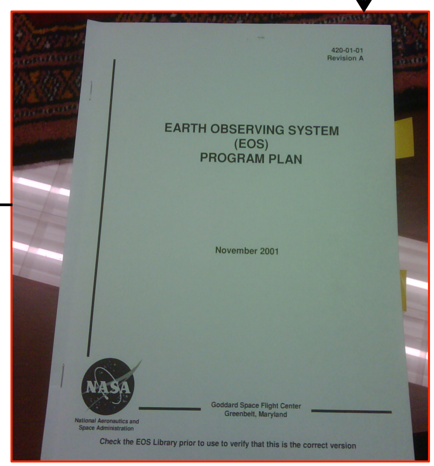
Atmospheric Chemistry **Terrestrial and Oceanic Ecosystems** **Natural Hazards**

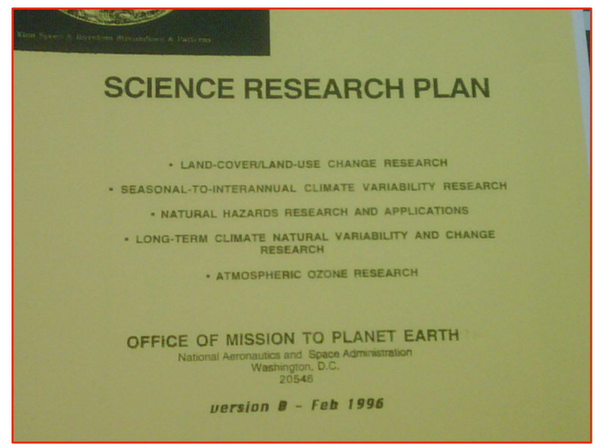
EOS Program Structure









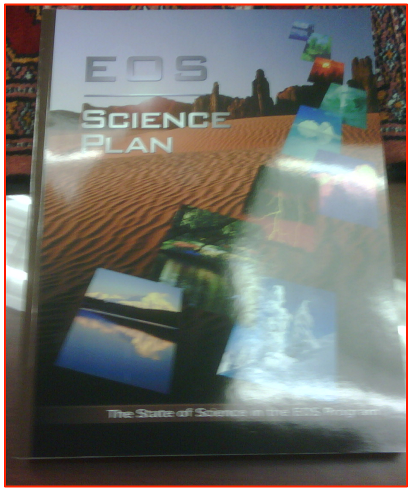


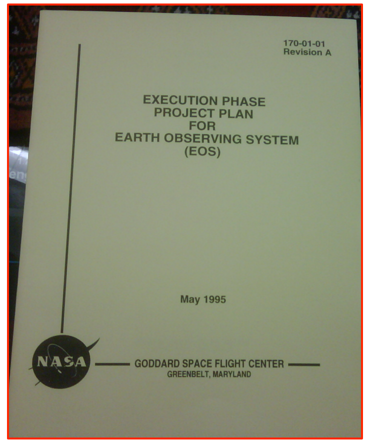
EOS Program Structure - continued

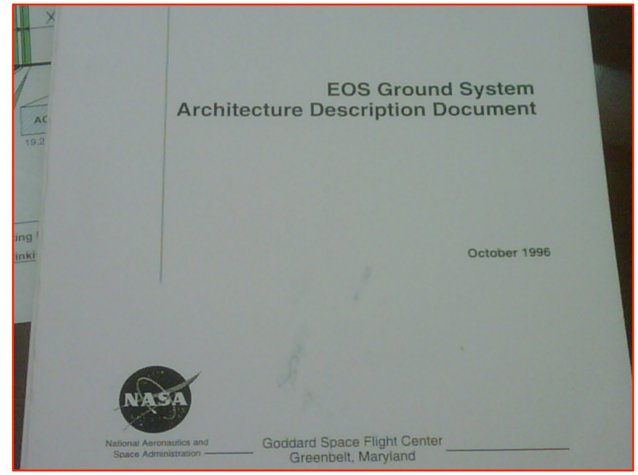
Science Research Plan

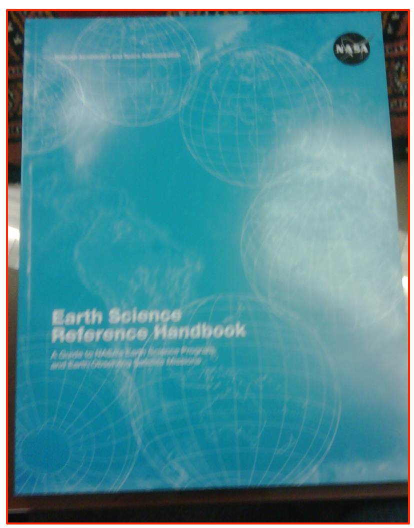
EOS Program Plan

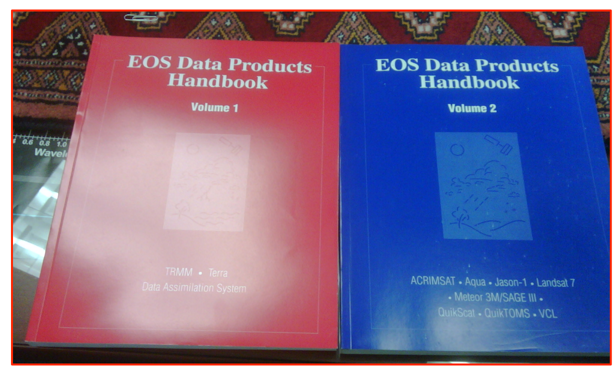
EOS Level 1 Requirements



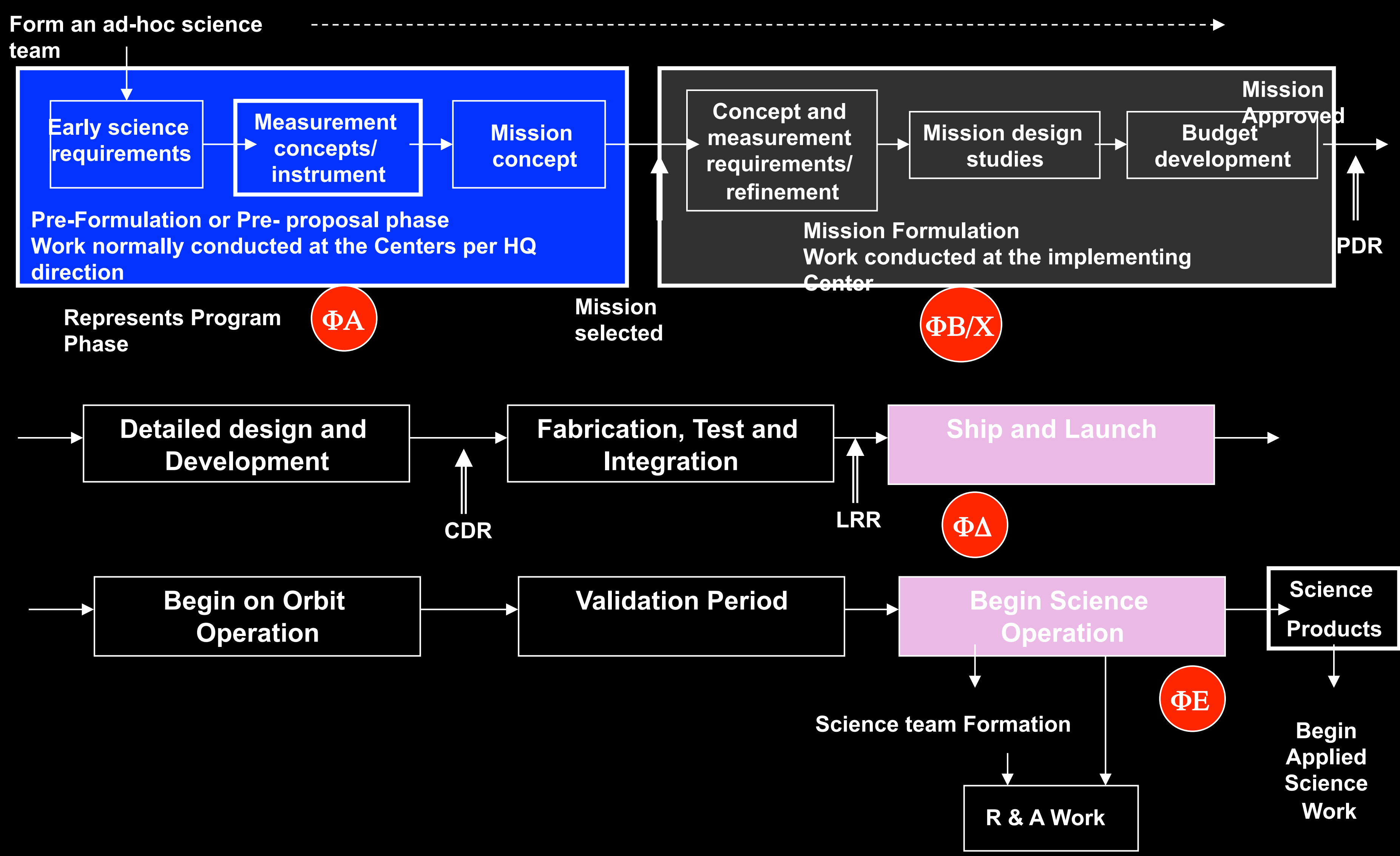








Generic Mission life Cycle



Lessons not Learned

Can we minimize Mission Cost:

Issue:

- Every large EOS mission such as Terra, Aqua and Aura was close to $1B range
- Budget estimate for Easton Study missions were also in the $700m -$1B range – OMB could not fund any of those
- Now, the Decadal missions are also falling in the same $ range.

Recommendation:

- We must take a hard look to control the measurement requirements (science, accuracy, pointing, platform configuration) and make hard decisions not satisfy every desire versus buildable requirements
- Accomplish or build a mission which may not satisfy every desired science but can at least provide a mission that can provide most of the data continuity

Easton Missions

		Earth Science Follow-on Missions Proposed Launch Schedule										
Mission	**Name**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**		
EOS-1	Land Cover Inventory Mission					X						
EOS-2/3	Climate Variability				X							
EOS-4	Total Solar Irradiance Mission					X						
EOS-5	Ocean Surface Wind Mission		X									
EOS-6	Ocean Surface Topography				X							
EOS-7a	Stratospheric Composition Monitoring Mission				X (1)			X (2)				
EOS-7b	Stratospheric Composition Monitoring Mission							X				
EOS-8	Land Topography and Surface Change Mission							X				
EOS-9	Global Precipitation Misssion				X							
EOS-10	Polar Altimetry Mission									X		
EX-1	Tropospheric Chemistry Research Mission						X					
EX-2/3	Aerosol Radiative and Cloud Radiation Mission								X			
EX-4a	Experimental Soil Moisture Measuring Mission			X								
EX-4b	Experimental Ocean Salinity Measuring Mission				X							
EX-5	Time-dependent Gravity Field Mapping Mission					X						
EX-6	Vegetation Recovery Mission						X					
EX-7	Cold Climate Land Process Research Mission					X						
OP-1	Advanced Technology Microwave Sounder						X					
OP-2	Tropospheric Wind Sounder						X					
OP-3	GPS Constellation for Atmospheric Sounding			X								
OP-4	Advanced Geostationary Sounder	X										
OP-5a	Volcanic Ash and Gas Emission Mapping Mission	TBD										
OP-5b	Advanced Geostationary Earth Imager	TBD										
OP-6	Special Event Imager				X							
OP-7	Geostationary Lightining Mapper				X							

EX - may be satisfied by some ESSP class missions
NMP- missions still be used as flight validation missions

Lessons not Learned - continued

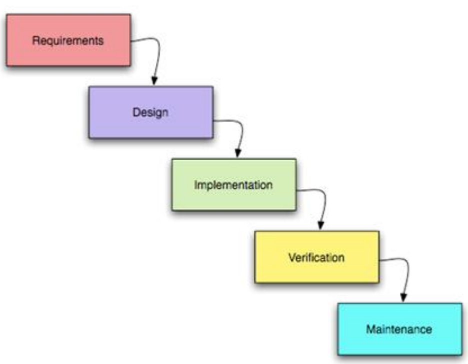
Operate as an Integrated Product Development team from mission inception:

<u>Issue:</u>

- Flight mission organizations have dominated the development process with some involvement from the science and other technical disciplines

<u>Recommendation:</u>

- It is crucial to involve the relevant team members (science, applications, SRM&QA, etc.) from the beginning
- Decadal missions are supposed to provide end-to-end science. It is very crucial to involve all the relevant disciplines through the mission life cycle (e.g., users, SRM&QA, hardware, software and others).



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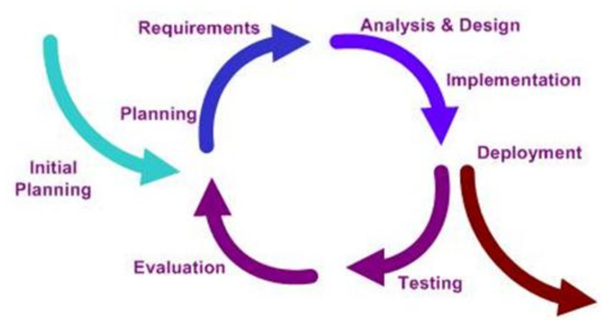


Lessons Learned

- MODIS, TRMM, and OMI instruments/satellite have been the “work horse” of Applied Science research. Sensors of these types will continue to have a high science utilization
- Direct Readout capability has been a tremendous contribution to the world community for studying disasters and other applications and building capacity.
- NASA is the only Agency with an open data policy. However, not well publicized.
- There is no “cookie cutter” solution to address the societal problems. Applying science data is continuing to be a challenge to conduct the applied research. Commercial high resolution can always be augmented.

Lessons Learned - continued

- Engage International partners from the beginning
  - Strong partnership was established with ESA, JAXA, INPE, CONAE, CNES during the EOS era.
  - We must continue this tradition to share mission development cost
- Engaging the National Academy and the User community– EOS was blessed by the Academy and had frequent external reviews
  - We waited too long to engage the Academy to define the decadal missions.
  - We must continue to pursue this to build advocacy, some level of community ownership and calibrate our development process

Lessons Learned - continued

- Technology Infusion: Take advantage of our technology development process and make every effort to infuse it in the decadal missions. This can be made as a mandatory requirement to the proposer.
- Program Management Structure: EOS had a comprehensive project management structure. We should take advantage of this experience and establish a similar or better structure for the decadal missions i.e.,
  - Level I requirements (including gap analysis and reducing mission overlaps)
  - Overall program plan
  - Implementation Strategy/plan
    - ✓ **Technology Infusion Plan**
    - ✓ **Data System Concept and Architecture**
  - Project management plan (including Centers)
  - Science Utilization Plan

NASA Earth Science research has lead the world by developing the recipe for the world community to get involved and build their own missions

Thank you

1998 Strategic Roadmap for the Earth Science Enterprise

1998-2002
Establish A Presence
Deliver world-class programs and cutting-edge technology through a Revolutionized NASA

2003-2007
Expand Our Horizons
Ensure continued U.S. leadership in space and aeronautics

2008-2023 and Beyond
Develop the Frontier
Expand human activity and space-based commerce in the frontiers of air and space

To advance and communicate **scientific knowledge** and understanding of the Earth...

Characterize the Earth System → **Understand Changes in the Earth System** → **Forecast & Assess the State of the Earth System**

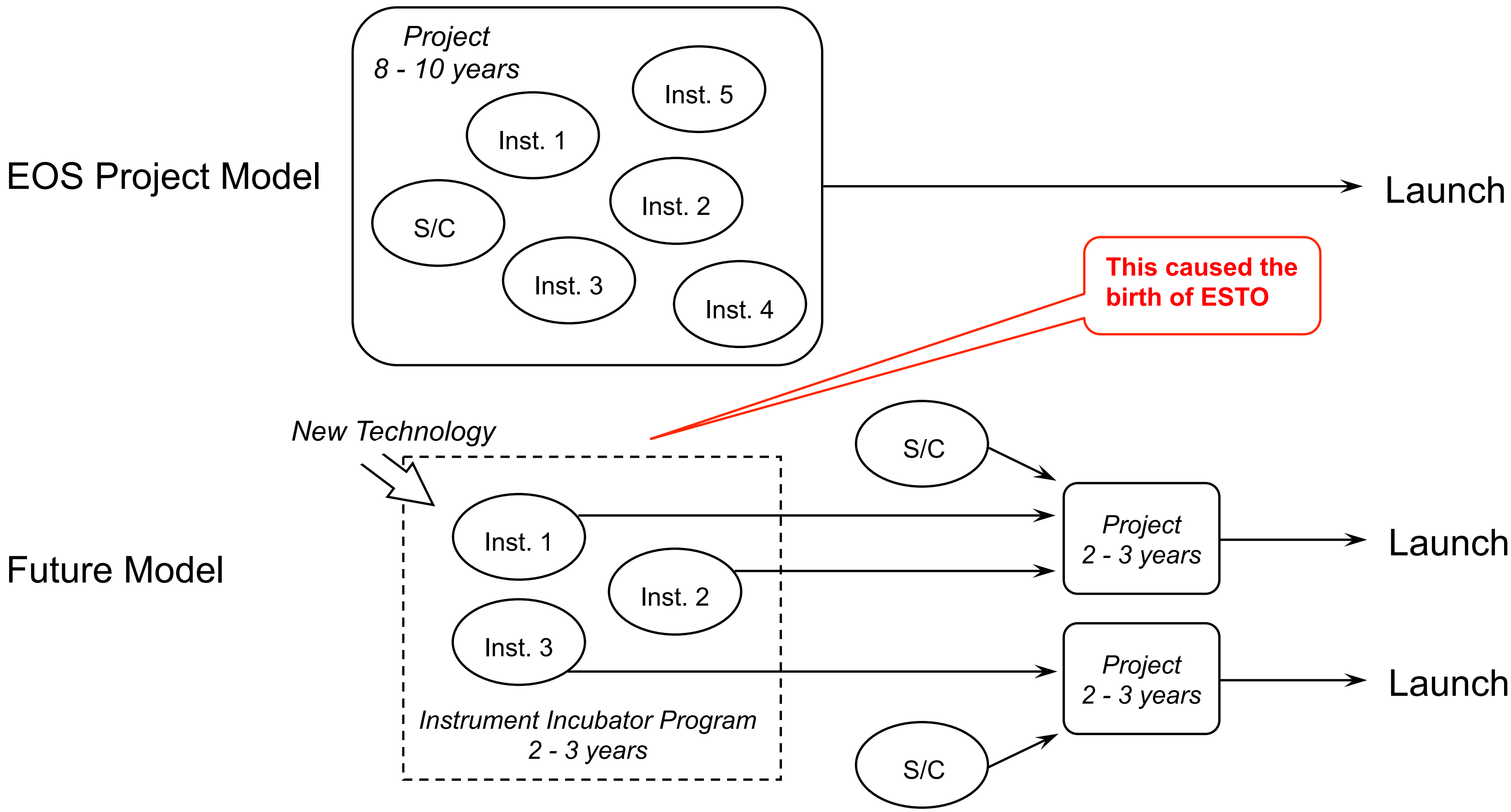
To explore, **use** and enable the development of space...

Enhance Information Access & Public Awareness → **Enable Effective Mix of Sources & Users; Enhance Curricula** → **Implement an International Global Observing Strategy; Next Generation of Earth Scientists**

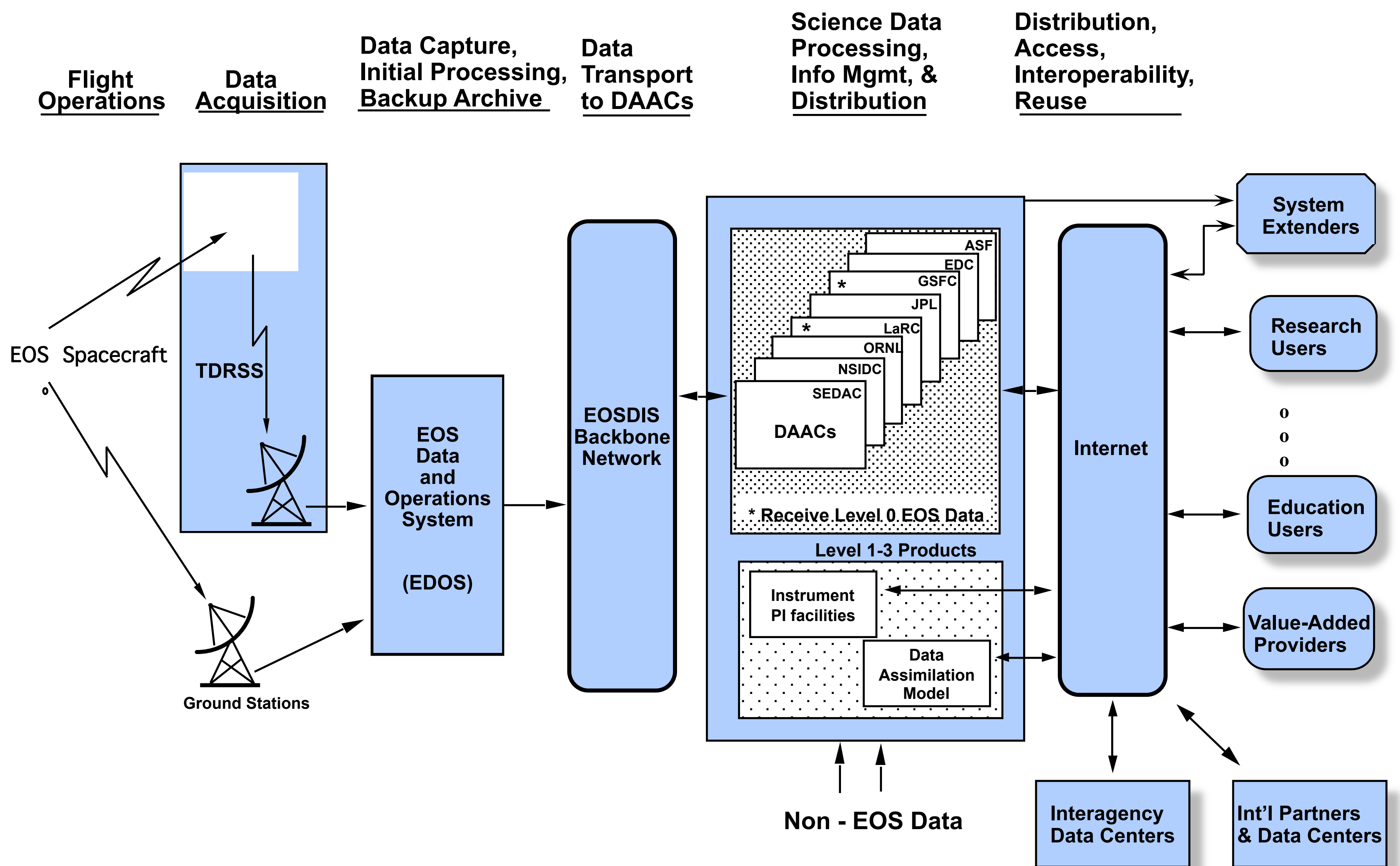
To research, develop, verify and **transfer... advanced technologies**

New Technology, New Applications & Expanding Remote Sensing Industry → **New Instruments for Operational Systems & Use of Commercial Systems** → **Widespread Use of Global Data in Economic & Environmental Decision-making**

Instrument Development Models



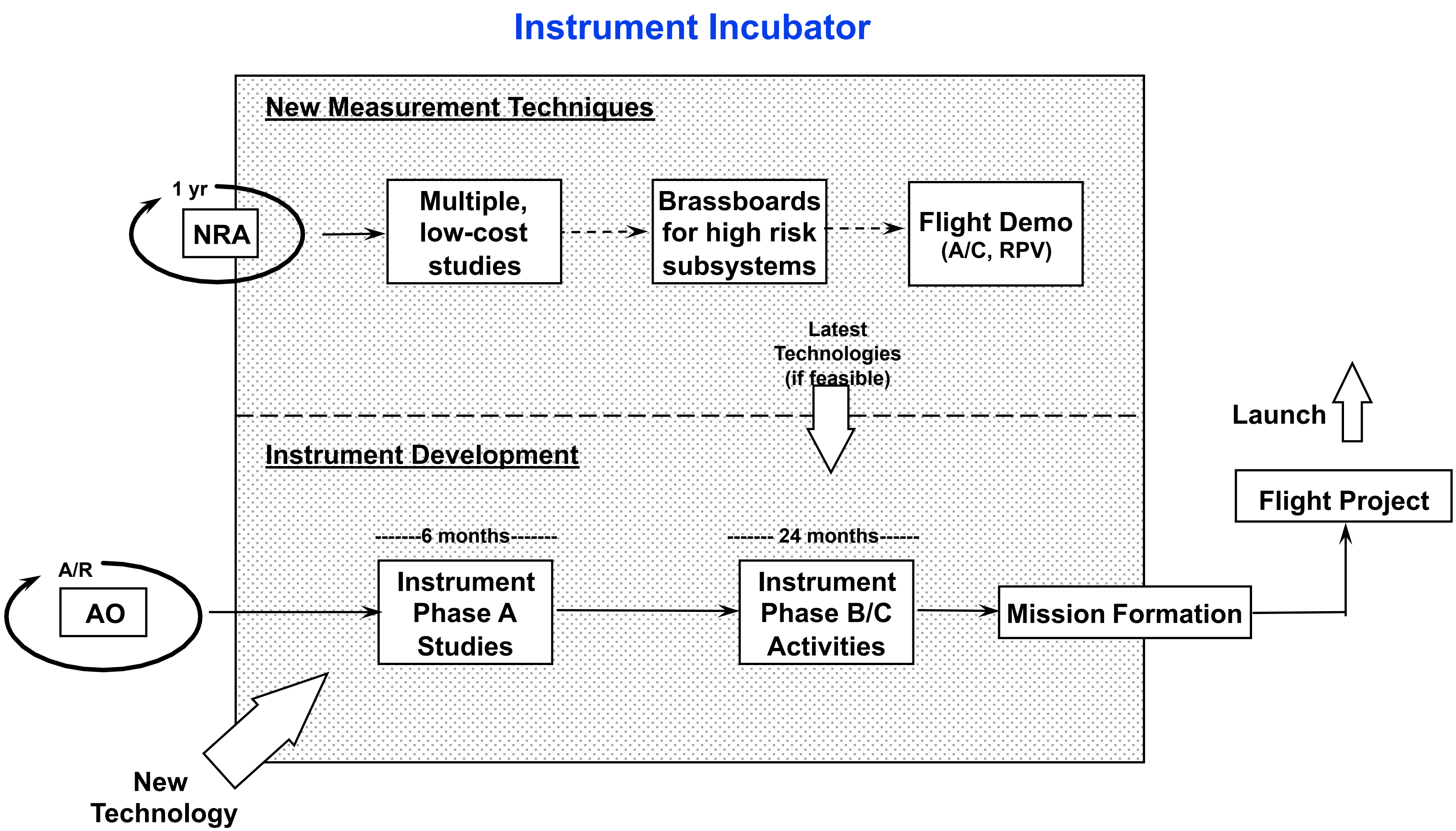
EOSDIS Functional Architecture



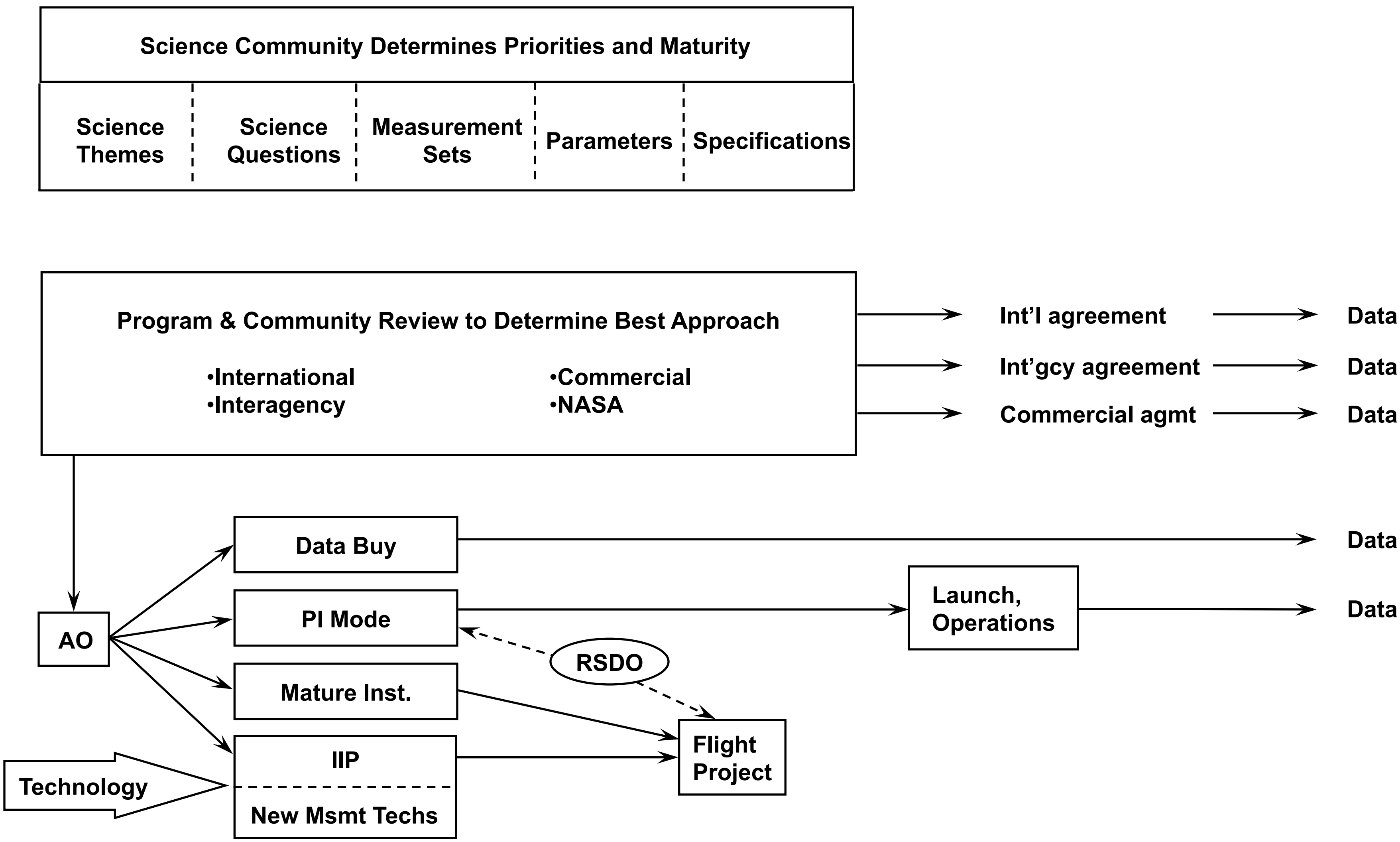
EOS era Research Program Science Themes

- Land Cover and Land Use Change Research
    - ***What are the nature and extent of land cover and land use change and the consequences for sustained productivity?***
- Seasonal-to-Interannual Climate Variability and Prediction
    - ***Can we enable regionally useful forecasts of precipitation and temperature on seasonal-to-interannual time frames?***
- Natural Hazards Research and Applications
    - ***Can we learn to predict natural hazards and mitigate natural disasters?***
- Long-term Climate: Natural Variability & Change Research
    - ***What are the causes and impacts of long-term climate variability, and can we distinguish natural from human-induced drivers?***
- Atmospheric Ozone Research
    - ***How and why are concentrations and distributions of atmospheric ozone changing?***

IIP Implementation Flow

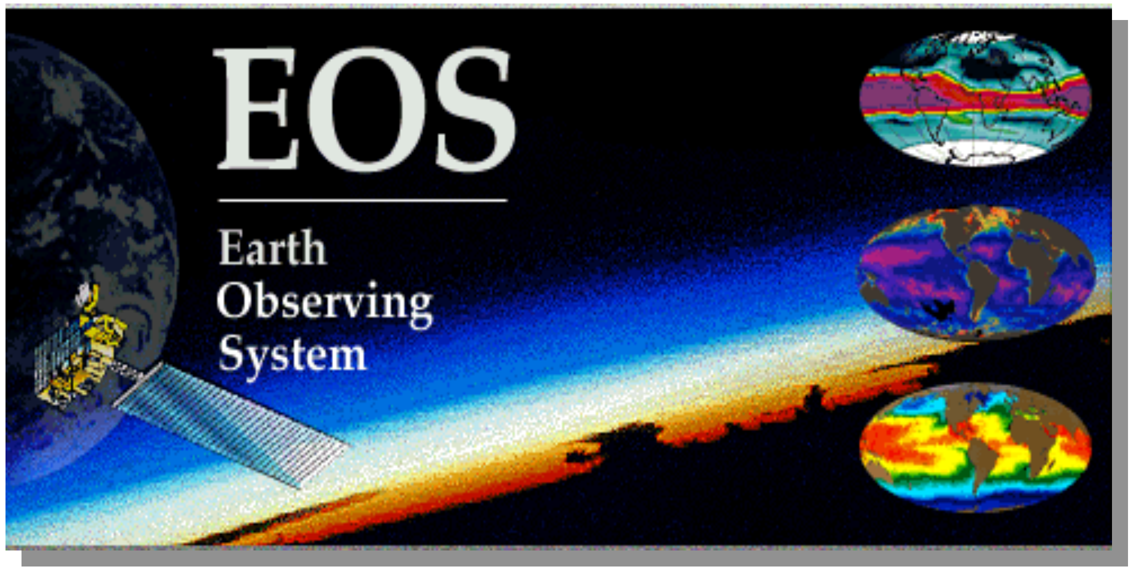


Implementation Model



EOS 24 Measurements

Atmosphere	1. Vegetation
	2. Biological Productivity
	3. Surface Temperature
	4. Precipitation
	5. Snow Cover
	6. Surface Elevation
	7. Land Use
	8. Fire Occurrence
Solar	9. Total Solar Irradiance
	10. Solar Spectral Irradiance
Cryosphere	11. Ice Sheet Elevation
	12. Ice Volume
Atmosphere	13. Clouds and Radiation
	14. Chemistry of Troposphere
	15. Chemistry of Stratosphere
	16. Aerosols
	17. Volcano Effects
	18. Meteorological Variables: (Temp/Humidity)
Ocean	19. Surface Temperature
	20. Phytoplankton and Biological Production
	21. Sea Ice
	22. Surface Wind Fields
	23. Ocean Circulation
	24. Sea Height



Missions	Research Objectives
AM	Clouds, aerosol and radiation balance, Characterization of the terrestrial ecosystem
PM	Clouds, precipitation, radiative balance, air-sea fluxes of energy and moisture
Chemistry	Behavior of ozone, other greenhouse gases and aerosols, and their impact on global climate
Landsat 7	Global land use and land cover change, Earth surface images for cartographic commercial applications
IceSat	Ice sheet mass balance, cloud top and land topography
ACRIM	Variability of total solar irradiance
SOLSTICE	Full disk solar ultraviolet irradiance
SAGE	Global profiles of atmospheric aerosols
SeaWinds	Effects of ocean winds on annual and interannual climate variation
CERES	Earth's radiation budget and atmospheric radiation
QuikScat	Ocean Surface winds

NASA